U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-265 586

Stockade Lake
Custer County
South Dakota

National Eutrophication Survey, Corvallis, Oreg

Prepared for

Corvallis Environmental Research Lab, Oreg

Dec 76

43

PB 265 586

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON

and

ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

G.P.O. 699-440

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE	5. REPORT DATE
Report on Stockade Lake, Custer County, South Dakota	Prepared December 1976
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Anonymous (National Eutrophication Survey Staff)	Working Paper # 625
9. PERFORMING ORGANIZATION NAME AND ADDRESS National Eutrophication Survey U.S. Environmental Protection Agency 200 S. W. 35th St. Corvallis, Oregon 97330	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Office of Research and Development U.S. Environmental Protection Agency 401 M Street, S. W. Washington, DC 20460	13. TYPE OF REPORT AND PERIOD COVERED Final - 1974 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Prepared in cooperation with the U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada 89114

16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		05B 05C

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release unlimited		43
	20. SECURITY CLASS *(This page)*	22. PRICE PC A03-MF A01

EPA Form 2220-1 (9-73)

REPORT
ON
STOCKADE LAKE
CUSTER COUNTY
SOUTH DAKOTA
EPA REGION VIII
WORKING PAPER No. 625

WITH THE COOPERATION OF THE
SOUTH DAKOTA DEPARTMENT OF ENVIRONMENTAL PROTECTION
AND THE
SOUTH DAKOTA NATIONAL GUARD

DECEMBER, 1976

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the South Dakota Departments of Environmental Protection and Game, Fish and Parks for professional involvement, to the South Dakota National Guard for conducting the tributary sampling phase of the Survey, and to those wastewater treatment plant operators who voluntarily provided effluent samples.

Allyn Lockner, Secretary, and Blaine Barker and Duane Murphy, Department of Environmental Quality; Douglas Hansen, Department of Game, Fish and Parks; and James Hayden, Director, State Lakes Preservation Committee provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

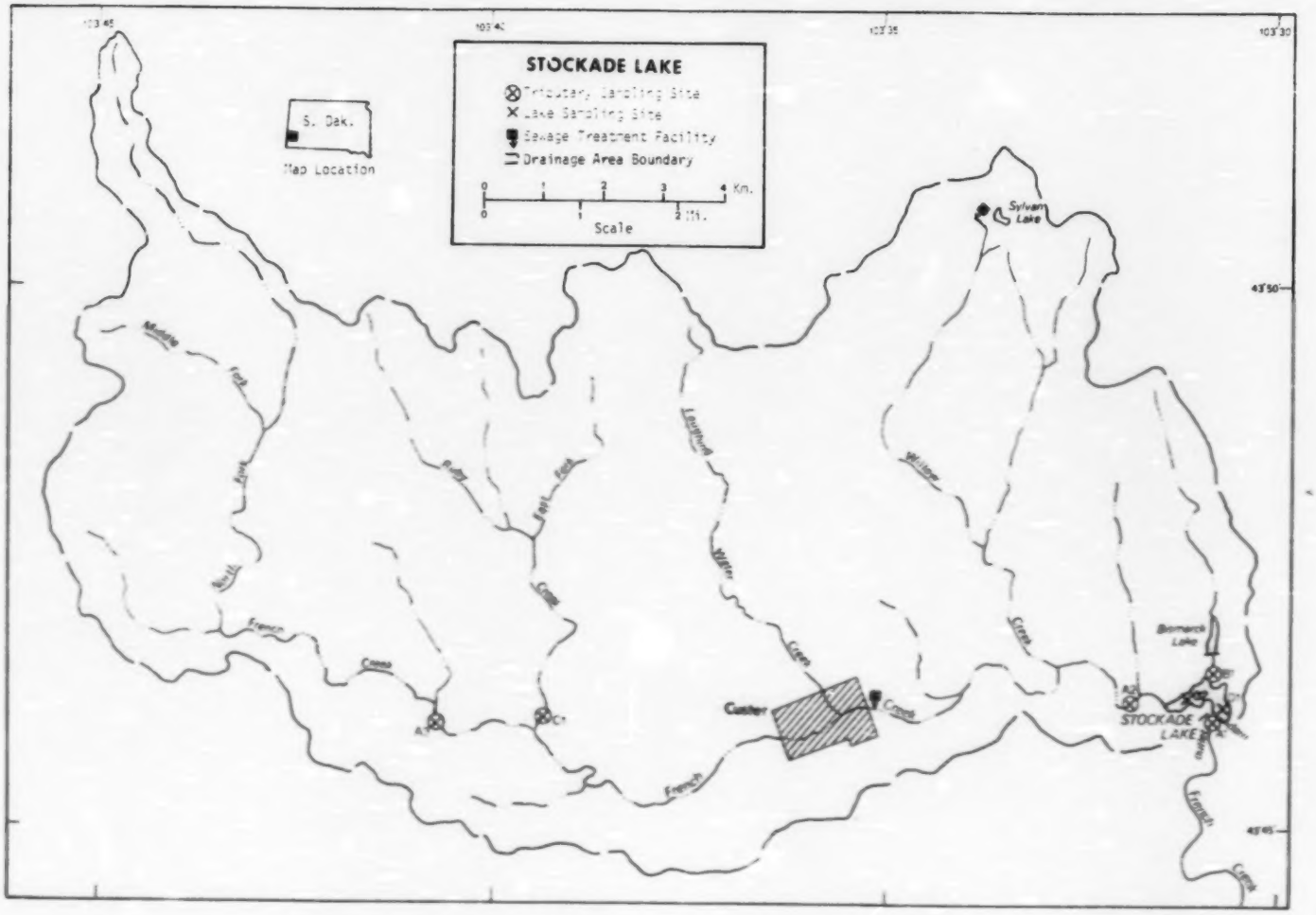
Major General Duane L. Corning, the Adjutant General of South Dakota, and Project Officer Colonel Robert D. Chalberg, who directed the volunteer efforts of the South Dakota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF SOUTH DAKOTA

LAKE NAME	COUNTY
Albert	Kingsbury
Alvin	Lincoln
Angostura	Fall River
Brant	Lake
Byron	Beadle
Clear	Marshall
Clear	Minnehaha
Cochrane	Deuel
Cottonwood	Spink
Deerfield	Pennington
Enemy Swim	Day
Herman	Lake
John	Hamlin
Kampeska	Codington
Madison	Lake
Mitchell	Davidson
Norden	Hamlin
East Oakwood	Brookings
West Oakwood	Brookings
Pactola	Pennington
Pickerel	Day
Poinsett	Brookings, Lake
Red Iron South	Marshall
Richmond	Brown
Roy	Marshall
Sand	Brown
Sheridan	Pennington
Stockdale	Custer
East Vermillion	McCook
Wall	Minnehaha
Waubay	Day


STOCKADE LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
0 1 2 3 4 Km.
0 1 2 Mi.
Scale
S. Dak.
Map Location
103°45'
103°40'
103°35'
103°30'
43°50'
43°45'
Sylvan Lake
Bismarck Lake
Custer
Custer Creek
STOCKADE LAKE
Middle Fork
South Fork
French Creek
Battle Creek
Legion Creek
Willow Creek
Grace Coolidge Creek
French Creek

STOCKADE LAKE

STORET NO. 4628

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Stockade Lake is eutrophic. It ranked twenty-third in overall trophic quality when the 31 South Dakota lakes sampled in 1974 were compared using a combination of six lake parameters*. Twenty-one of the lakes had less median total phosphorus, 22 had less median dissolved orthophosphorus, 17 had less and two had the same median inorganic nitrogen, 15 had less mean chlorophyll a, and eight had greater mean Secchi disc transparency. Marked depression or depletion of dissolved oxygen with depth occurred in July and September at both sampling stations.

Survey limnologists observed algal blooms in progress in July and September.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Stockade Lake was nitrogen limited at the times the samples were collected (04/24/74 and 09/11/74).

The lake data indicate nitrogen limitation at all sampling times.

C. Nutrient Controllability:

1. Point sources--Known point sources contributed 35.7% of the total phosphorus load to Stockade Lake during the sampling

*See Appendix A.

year. The City of Custer added 29.6% of the total phosphorus load, and Sylvan Lake contributed 6.1%.

The present phosphorus loading of 1.25 $g/m^2/yr$ is 2.3 times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 12).

On the basis of Survey data, even complete removal of phosphorus at the two point sources would still leave a loading nearly 1.5 times the eutrophic loading. However, the apparent marked loss of both phosphorus and nitrogen during the year (see pages 10 and 11) indicates Survey sampling was not intensive enough to determine the actual nutrient loadings.

2. Non-point sources--It is estimated that non-point sources contributed 64.3% of the total phosphorus load reaching Stockade Lake during the sampling year. French Creek added 54.5% of the total, and the ungaged minor tributaries and immediate drainage contributed an estimated 8.3%.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 0.53 kilometers^2.
2. Mean depth: 5.8 meters.
3. Maximum depth: 12.8 meters.
4. Volume: 3.074×10^6 m^3.
5. Mean hydraulic retention time: 274 days (based on outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
French Creek	173.5	0.123
Minor tributaries & immediate drainage -	28.0	0.012
Totals	201.5	0.135

2. Outlet -

French Creek	202.0**	0.130

C. Precipitation***:

1. Year of sampling: 43.82 centimeters.
2. Mean annual: 41.73 centimeters.

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† Table of metric conversions--Appendix B.
†† Murphey, 1974.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Stockade Lake was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at two stations on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first and last visits, a single 18.9-liter depth-integrated sample was collected from each of the stations for chlorophyll *a* analysis. The maximum depths sampled were 10.7 meters at station 1 and 5.2 meters at station 2.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR STOCKADE LAKE
STORET CODE 4628

PARAMETER	1ST SAMPLING (4/24/74) 2 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (7/15/74) 2 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (9/11/74) 2 SITES RANGE	MEAN	MEDIAN
TEMP (C)	5.6 - 10.6	8.4	8.7	13.1 - 24.8	20.3	21.9	10.0 - 16.6	14.8	16.0
DISS OXY (MG/L)	6.2 - 11.4	9.2	9.4	0.0 - 13.0	5.3	1.2	0.0 - 10.2	4.5	4.8
CNDCTVY (MCROMO)	184. - 206.	196.	197.	278. - 313.	304.	309.	215. - 249.	228.	225.
PH (STAND UNITS)	****** -**********			7.3 - 9.6	8.5	9.0	6.8 - 9.1	8.4	8.8
TOT ALK (MG/L)	113. - 119.	116.	115.	113. - 145.	125.	123.	116. - 163.	129.	120.
TOT P (MG/L)	0.131 - 0.233	0.190	0.196	0.078 - 0.766	0.315	0.154	0.313 - 1.320	0.599	0.387
ORTHO P (MG/L)	0.066 - 0.107	0.082	0.081	0.028 - 0.606	0.178	0.073	0.222 - 1.160	0.492	0.287
NO2+NO3 (MG/L)	0.030 - 0.060	0.037	0.030	0.040 - 0.120	0.072	0.070	0.020 - 0.050	0.024	0.020
AMMONIA (MG/L)	0.030 - 0.070	0.054	0.060	0.020 - 1.140	0.188	0.060	0.070 - 3.940	1.073	0.370
KJEL N (MG/L)	0.700 - 1.000	0.886	0.900	0.500 - 1.800	1.256	1.200	1.100 - 4.400	2.033	1.600
INORG N (MG/L)	0.060 - 0.120	0.091	0.090	0.080 - 1.230	0.260	0.150	0.090 - 3.960	1.098	0.400
TOTAL N (MG/L)	0.730 - 1.060	0.923	0.930	0.620 - 1.890	1.328	1.270	1.120 - 4.420	2.058	1.620
CHLRPYL A (UG/L)	24.0 - 24.8	24.4	24.4	32.5 - 63.4	47.9	47.9	2.4 - 5.3	3.8	3.8
SECCHI (METERS)	1.8 - 2.1	2.0	2.0	1.5 - 1.5	1.5	1.5	1.5 - 1.8	1.7	1.7

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/24/74	1. Centric diatoms	16,809
	2. Cryptomonas sp.	2,873
	3. Flagellates	2,135
	4. Unidentified cells	349
	5. Asterionella sp.	194
	Other genera	117
	Total	22,477
07/15/74	1. Aphanizomenon sp.	3,098
	2. Phormidium sp.	2,278
	3. Microcystis sp.	516
	4. Fragilaria sp.	395
	5. Staurastrum sp.	152
	Other genera	273
	Total	6,712
09/11/74	1. Aphanizomenon sp.	14,916
	2. Chroomonas sp.	437
	3. Scenedesmus sp.	131
	4. Oocystis sp.	131
	5. Melosira sp.	87
	Other genera	351
	Total	16,053

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
04/24/74	1	24.8
	2	24.0
07/15/74	1	32.5
	2	63.4
09/11/74	1	2.4
	2	5.3

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. April sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.090	0.658	6.7
0.050 P	0.140	0.658	5.8
0.050 P + 1.0 N	0.140	1.658	27.7
1.0 N	0.090	1.658	31.2

b. September sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.420	1.270	27.5
0.050 P	0.470	1.270	31.4
0.050 P + 1.0 N	0.470	2.270	55.0
1.0 N	0.420	2.270	52.2

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity of Stockade Lake was high when the assay samples were taken in April and September, 1974. The addition of nitrogen alone resulted in significant increases in yield, but no such response occurred with the addition of only phosphorus. Therefore, nitrogen limitation is indicated.

The lake data indicate nitrogen limitation at all sampling times; i.e., the mean inorganic nitrogen to orthophosphorus ratios were 1 to 1 in April and July and 2 to 1 in September.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the South Dakota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of April and May when two samples were collected. Sampling was begun in October, 1974, and was completed in July, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the South Dakota District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the adjusted nutrient loads at station A-2, in kg/km^2/year, and multiplying by the ZZ area in km^2.

The operators of the Custer and Sylvan Lake wastewater treatment plants provided monthly effluent samples and corresponding flow data.

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* See Working Paper No. 175.

A. Waste Sources:

1. Known domestic* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Custer	1,500	tr. filter + pond	892.4	French Creek
Sylvan Lake	3,300	stab. ponds	106.5	Willow Creek

2. Known industrial - None

* Treatment plant questionnaires.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
French Creek	360	54.5
b. Minor tributaries & immediate drainage (non-point load) -	55	8.3
c. Known domestic STP's -		
Custer	195	29.6
Sylvan Lake	40	6.1
d. Septic tanks - Unknown	?	-
e. Known industrial - None	-	-
f. Direct precipitation* -	10	1.5
Total	660	100.0

2. Outputs -

Lake outlet - French Creek 1,075

3. Net annual P loss - 415 kg.

* See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
French Creek	3,865	69.1
b. Minor tributaries & immediate drainage (non-point load) -	615	11.0
c. Known domestic STP's -		
Custer	430	7.7
Sylvan Lake	110	2.0
d. Septic tanks - Unknown	?	-
e. Known industrial - None	-	-
f. Direct precipitation* -	570	10.2
Total	5,590	100.0

2. Outputs -

Lake outlet - French Creek	14,780

3. Net annual N loss - 9,190 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
French Creek	2	22

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
French Creek at A-3	0.065	1.931
Bismarck Lake outlet	0.070	1.183
Ruby Creek	0.053	1.659

* See Working Paper No. 175.

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	1.25	loss*	10.5	loss*

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Stockade Lake:

"Dangerous" (eutrophic loading)	0.54
"Permissible" (oligotrophic loading)	0.27

* There was an apparent loss of nitrogen and phosphorus during the sampling year. This may have been due to nitrogen fixation in the lake, solubilization of previously sedimented phosphorus and nitrogen, recharge with nutrient-rich ground water, unknown and unsampled point sources discharging directly to the lake, or (probably) insufficient tributary sampling.

V. LITERATURE REVIEWED

Murphey, Duane G., 1974. Personal communication (lake morphometry). SD Dept. of Env. Prot., Pierre.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	SSD-MEAN SEC	MEAN CHLORA	1S-MIN DO	MEDIAN DISS ORTHO P
4601	LAKE ALBERT	0.321	0.170	489.111	106.289	9.200	0.019
4602	ALVIN LAKE	0.067	0.970	442.833	4.700	9.400	0.017
4603	ANGOSTURA RESERVOIR	0.019	0.160	423.333	3.717	13.000	0.005
4604	BRANT LAKE	0.194	0.130	432.833	34.150	11.800	0.113
4605	LAKE BYRON	0.443	0.370	488.333	149.350	9.000	0.146
4606	CLEAR LAKE	0.027	0.075	430.167	11.983	8.800	0.009
4607	CLEAR LAKE	1.400	0.270	495.333	691.000	7.000	0.468
4608	COCHRANE LAKE	0.037	0.150	446.000	15.683	15.000	0.008
4609	COTTONWOOD LAKE	0.685	0.265	490.333	112.017	8.600	0.417
4610	DEERFIELD RESERVOIR	0.033	0.080	303.333	3.650	15.000	0.022
4611	ENEMY SWIM LAKE	0.037	0.085	442.600	14.200	8.200	0.013
4612	LAKE HERMAN	0.340	0.155	485.000	58.733	8.600	0.174
4613	ST JOHN LAKE	0.349	0.080	489.400	120.880	9.800	0.025
4614	LAKE KAMPESKA	0.220	0.105	468.889	20.567	8.200	0.128
4615	MADISON LAKE	0.259	0.090	445.555	22.578	14.000	0.107
4616	LAKE MITCHELL	0.099	0.085	465.833	14.883	13.800	0.015
4617	LAKE NORDEN	0.256	0.165	488.667	46.800	10.000	0.050
4618	OAKWOOD LAKE EAST	0.146	0.175	487.000	113.600	10.000	0.009
4619	OAKWOOD LAKE WEST	0.181	0.135	485.833	159.667	9.600	0.021
4620	PACTOLA RESERVOIR	0.011	0.070	248.444	1.478	11.000	0.006
4621	PICKEREL LAKE	0.049	0.095	439.833	15.833	9.600	0.009
4622	LAKE POINSETT	0.115	0.315	468.444	40.211	10.000	0.023
4623	LAKE RED IRON SOUTH	0.042	0.110	430.333	6.883	7.600	0.010
4624	RICHMOND LAKE	0.187	0.150	410.000	18.467	10.000	0.144
4625	ROY LAKE	0.034	0.070	431.000	13.333	11.000	0.010
4626	SAND LAKE	0.489	0.110	471.800	65.790	12.800	0.288
4627	SHERIDAN LAKE	0.053	0.105	394.000	15.433	15.000	0.016
28	STOCKADE LAKE	0.233	0.150	432.000	25.400	15.000	0.109

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4629	LAKE VERMILLION	0.211	0.100	472.833	100.800	9.200	0.092
4630	WALL LAKE	0.194	0.160	441.667	55.267	7.400	0.076
4631	MAUBAY LAKE NORTH	0.098	0.145	469.555	127.033	11.400	0.023

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4601	LAKE ALBERT	20 (6)	20 (6)	10 (3)	23 (7)	68 (20)	60 (18)	201
4602	ALVIN LAKE	67 (20)	0 (0)	57 (17)	90 (27)	63 (19)	63 (19)	340
4603	ANGOSTURA RESERVOIR	97 (29)	30 (9)	87 (26)	93 (28)	20 (6)	100 (30)	427
4604	BRANT LAKE	40 (12)	53 (16)	70 (21)	47 (14)	27 (8)	23 (7)	260
4605	LAKE BYRON	10 (3)	3 (1)	17 (5)	7 (2)	73 (22)	13 (4)	123
4606	CLEAR LAKE	93 (28)	93 (28)	83 (25)	83 (25)	77 (23)	90 (27)	519
4607	CLEAR LAKE	0 (0)	10 (3)	0 (0)	0 (0)	100 (30)	0 (0)	110
4608	COCHRANE LAKE	83 (25)	40 (11)	50 (15)	67 (20)	5 (0)	93 (28)	338
4609	COTTONWOOD LAKE	3 (1)	13 (4)	3 (1)	20 (6)	82 (24)	3 (1)	124
4610	DEERFIELD RESERVOIR	90 (27)	88 (26)	97 (29)	97 (29)	5 (0)	53 (16)	430
4611	ENEMY SWIM LAKE	80 (24)	82 (24)	60 (18)	77 (23)	88 (26)	73 (22)	460
4612	LAKE HERMAN	17 (5)	33 (10)	27 (8)	33 (10)	82 (24)	10 (3)	202
4613	ST JOHN LAKE	13 (4)	88 (26)	7 (2)	13 (4)	53 (16)	43 (13)	217
4614	LAKE KAMPESKA	33 (10)	65 (19)	40 (12)	57 (17)	88 (26)	20 (6)	303
4615	MADISON LAKE	27 (8)	77 (23)	53 (16)	53 (16)	13 (4)	30 (9)	253
4616	LAKE MITCHELL	60 (18)	82 (24)	47 (14)	73 (22)	17 (5)	70 (21)	349
4617	LAKE NORDEN	23 (7)	23 (7)	13 (4)	40 (12)	45 (12)	40 (12)	184
4618	OAKWOOD LAKE EAST	53 (16)	17 (5)	20 (6)	17 (5)	45 (12)	85 (25)	237
4619	OAKWOOD LAKE WEST	50 (15)	50 (15)	23 (7)	3 (1)	58 (17)	57 (17)	241
4620	PACTOLA RESERVOIR	100 (30)	98 (29)	100 (30)	100 (30)	35 (10)	97 (29)	530
4621	PICKEREL LAKE	73 (22)	73 (22)	67 (20)	63 (19)	58 (17)	85 (25)	419
4622	LAKE POINSETT	57 (17)	7 (2)	43 (13)	43 (13)	45 (12)	47 (14)	242
4623	LAKE RED IRON SOUTH	77 (23)	58 (17)	80 (24)	87 (26)	93 (28)	78 (23)	473
4624	RICHMOND LAKE	47 (14)	40 (11)	90 (27)	60 (18)	45 (12)	17 (5)	299
4625	ROY LAKE	87 (26)	98 (29)	77 (23)	80 (24)	35 (10)	78 (23)	455
4626	SAND LAKE	7 (2)	58 (17)	33 (10)	30 (9)	23 (7)	7 (2)	158
4627	SHERIDAN LAKE	70 (21)	65 (19)	93 (28)	70 (21)	5 (0)	67 (20)	370
4628	STOCKADE LAKE	30 (9)	48 (11)	73 (22)	50 (15)	5 (0)	27 (8)	225

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4629	LAKE VERMILLION	37 (11)	70 (21)	30 (9)	27 (8)	68 (20)	33 (10)	265
4630	WALL LAKE	43 (13)	27 (8)	63 (19)	37 (11)	97 (29)	37 (11)	304
4631	WAUBAY LAKE NORTH	63 (19)	47 (14)	37 (11)	10 (3)	30 (9)	50 (15)	237

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	4620	PACTOLA RESERVOIR	530
2	4606	CLEAR LAKE	519
3	4623	LAKE RED IRON SOUTH	473
4	4611	ENEMY SWIM LAKE	460
5	4625	ROY LAKE	455
6	4610	DEERFIELD RESERVOIR	430
7	4603	ANGOSTURA RESERVOIR	427
8	4621	PICKEREL LAKE	419
9	4627	SHERIDAN LAKE	370
10	4616	LAKE MITCHELL	349
11	4602	ALVIN LAKE	340
12	4608	COCHRANE LAKE	338
13	4630	WALL LAKE	304
14	4614	LAKE KAMPESKA	303
15	4624	RICHMOND LAKE	299
16	4629	LAKE VERMILLION	265
17	4604	BRANT LAKE	260
18	4615	MADISON LAKE	253
19	4622	LAKE POINSETT	242
20	4619	OAKWOOD LAKE WEST	241
21	4631	WAUBAY LAKE NORTH	237
22	4618	OAKWOOD LAKE EAST	237
23	4628	STOCKADE LAKE	225
24	4613	ST JOHN LAKE	217
25	4612	LAKE HERMAN	202
26	4601	LAKE ALBERT	201
27	4617	LAKE NORDEN	184
	4626	SAND LAKE	158

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
29	4609	COTTONWOOD LAKE	124
30	4605	LAKE BYRON	123
31	4607	CLEAR LAKE	110

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR SOUTH DAKOTA 05/03/76

LAKE CODE 4628 STOCKADE

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 202.0

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
4628A1	202.0	0.085	0.085	0.085	0.142	0.170	0.340	0.227	0.170	0.085	0.057	0.057	0.057	0.130
4628A2	173.5	0.085	0.085	0.085	0.170	0.198	0.283	0.170	0.142	0.085	0.057	0.057	0.057	0.123
4628ZZ	28.5	0.0	0.0	0.0	0.028	0.028	0.057	0.028	0.0	0.0	0.0	0.0	0.0	0.012

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 202.0
SUM OF SUB-DRAINAGE AREAS = 202.0
TOTAL FLOW IN = 1.61
TOTAL FLOW OUT = 1.56

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
4628A1	10	74	0.003	12	0.003				
	11	74	0.003	10	0.003				
	12	74	0.0	16	0.0				
	1	75	0.0	14	0.0				
	2	75	0.0	26	0.0				
	3	75	0.0	12	0.0				
	4	75	0.006	21	0.008				
	5	75	0.142	5	0.227				
	6	75	0.085	11	0.057	24	0.057		
	7	75	0.057	25	0.028				
	8	75	0.028	16	0.014				
	9	75	0.028	17	0.008				
4628A2	10	74	0.006	12	0.008				
	11	74	0.003	10	0.006				
	12	74	0.0	16	0.0				
	1	75	0.0	14	0.0				
	2	75	0.0	26	0.0				
	3	75	0.008	12	0.0				
	4	75	0.028	21	0.014				
	5	75	0.028	5	0.014	22	0.028		
	6	75	0.028	11	0.014	24	0.028		
	7	75	0.028	25	0.008				
	8	75	0.008	16	0.003				
	9	75	0.008	17	0.003				
4628ZZ	10	74	0.003						
	11	74	0.0						
	12	74	0.0						
	1	75	0.0						
	2	75	0.0						
	3	75	0.0						
	4	75	0.006						
	5	75	0.006						
	6	75	0.006						
	7	75	0.003						
	8	75	0.003						
	9	75	0.0						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/05/03

462801
43 45 50.0 103 30 45.0 3
STOCKADE LAKE
46033 SOUTH DAKOTA

090491

11EPALES 2111202
0034 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/24	16 05	0000	9.2		72	197		115	0.060	0.800	0.030	0.067
	16 05	0005	8.7	11.4		197		114	0.070	1.000	0.050	0.085
	16 05	0015	6.9	8.4		190		118	0.050	0.900	0.030	0.081
	16 05	0030	5.6	6.2		184		119	0.070	0.800	0.030	0.107
74/07/15	14 50	0000	24.4	13.0	60	313	9.60	113	0.060	1.200	0.070	0.028
	14 50	0005	21.9	10.0		311	9.50	117	0.050	1.200	0.060	0.046
	14 50	0010	20.9	1.2		311	7.30	123	0.170	1.200	0.040	0.109
	14 50	0020	13.1	0.0		278	7.30	137	1.140	1.800	0.090	0.327
	14 50	0035	16.8	0.0			7.40	145	0.030	0.500	0.120	0.606
74/09/11	14 00	0000	16.6	10.2	60	215	9.01	116	0.070	1.900	0.020K	0.222
	14 00	0005	16.3	8.0		221	9.01	118	0.160	1.100	0.020K	0.265
	14 00	0015	15.3	1.2		225	8.43	120	0.590	1.600	0.020K	0.378
	14 00	0025	11.6	0.0		237	6.83	157	3.190	3.000	0.020K	1.150
	14 00	0035	10.0	0.0		249	6.83	163	3.940	4.400	0.020K	1.160

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/24	16 05	0000	0.161	24.8	
	16 05	0005	0.207		
	16 05	0015	0.190		
	16 05	0030	0.213		
74/07/15	14 50	0000	0.078	32.5	
	14 50	0005	0.134		
	14 50	0010	0.230		
	14 50	0020	0.668		
	14 50	0035	0.766		
74/09/11	14 00	0000	0.320	2.4	
	14 00	0005	0.332		
	14 00	0015	0.467		
	14 00	0025	1.320		
	14 00	0035	1.300		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/03

462802
43 46 02.0 103 31 10.0 4
STOCKADE LAKE
46033 SOUTH DAKOTA
090491

11EPALES 2111202
0018 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/24	16	25 0000	10.6		84	202		118	0.060	0.700	0.030	0.066
	16	25 0005	10.1	10.6		206		113	0.040	1.000	0.060	0.093
	16	25 0014	7.9	9.4		194		114	0.030	1.000	0.030	0.074
74/07/15	15	30 0000	24.8	1.0	60	306	9.40	116	0.080	1.200	0.070	0.057
	15	30 0005	23.5	12.4		303	9.40	115	0.060	1.500	0.060	0.046
	15	30 0010	22.1	10.0		312	9.00	124	0.080	1.000	0.080	0.073
	15	30 0015	15.2	0.0		295	7.70	133	0.020	1.700	0.060	0.309
74/09/11	14	35 0000	16.3	8.6	72	219	9.09	117	0.190	1.500	0.020K	0.253
	14	35 0005	16.2	7.4		223	8.99	118	0.250	1.400	0.050	0.287
	14	35 0010	16.0	4.8		229	8.79	123	0.370	1.500	0.030	0.287
	14	35 0017	15.1	0.2		233	8.37	129	0.900	1.900	0.020K	0.425

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/24	16	25 0000	0.131	24.0	
	16	25 0005	0.233		
	16	25 0014	0.196		
74/07/15	15	30 0000	0.108	63.4	
	15	30 0005	0.139		
	15	30 0010	0.154		
	15	30 0015	0.554		
74/09/11	14	35 0000	0.313	5.3	
	14	35 0005	0.365		
	14	35 0010	0.387		
	14	35 0017	0.584		

K VALUE KNOWN TO BE
LESS THAN INDICATED

APPENDIX E

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 76/05/04

4628A1
43 45 50.0 103 30 50.0 4
FRENCH CREEK
46033 7.5 CUSTER
D/STOCKADE LAKE 090491
US HWY ALT 16 BRDG 4 MI E OF CUSTER
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/04/21	13 30		0.005	2.400	0.035	0.040	0.180
75/05/05	13 30		0.005	4.200	0.230	0.055	0.550
75/05/22	13 15		0.920	1.400	0.040	0.005	0.020
75/06/11	08 45		0.015	0.950	0.040	0.020	0.050
75/06/24	09 10		0.005	1.450	0.035	0.060	0.100
75/07/25	08 15		0.025	8.800	0.055	0.175	0.590

STORET RETRIEVAL DATE 76/05/04

4628A2
43 46 10.0 103 32 10.0 4
FRENCH CREEK
46033 7.5 CUSTER
T/STOCKADE LAKE 040491
US HWY ALT 16 BRDG 3 MI E OF CUSTER
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/12	13	20	0.024	0.400	0.040	0.380	0.430
74/11/10	13	00	0.320	1.000	0.015	0.108	0.115
75/04/21	13	15	0.105	1.050	0.055	0.065	0.110
75/05/05	13	15	0.010	0.100	0.050	0.070	0.115
75/05/22	13	00	0.070	1.750	0.035	0.060	0.150
75/06/11	08	30	0.080	0.900	0.060	0.070	0.130
75/06/24	08	45	0.055	0.700	0.045	0.080	0.160
75/07/25	08	00	0.050	1.050	0.030	0.142	0.190

30.

STORET RETRIEVAL DATE 76/05/04

4628A3
43 46 10.0 103 40 35.0 4
FRENCH CREEK
46033 7.5 HERNE
T/STOCKADE LAKE
SEC RD BRDG 3 MI NW OF JCT WITH US HWY 16
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/04/21	14 00		0.030	1.300	0.030	0.030	0.060
75/05/05	14 00		0.005	0.400	0.025	0.020	0.050K
75/05/22	13 50		0.010	2.200	0.040	0.025	0.030
75/06/11	09 15		0.010	1.000	0.040	0.020	0.040
75/06/24	09 45		0.010	5.800	0.075	0.020	0.040
75/07/25	08 40		0.020	0.800	0.085	0.040	0.170

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

462881
43 46 25.0 103 30 50.0 4
BISMARK LAKE OUTLET
46033 7.5 CUSTER
T/STOCKADE LAKE 090491
SEC RD BRDG 4 MI W OF CUSTER
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/04/21	13 25		0.005	1.700	0.015	0.030	0.100
75/05/05	13 20		0.005	1.025	0.005	0.015	0.070
75/05/22	13 05		0.025	1.150	0.055	0.020	0.070
75/06/11	08 40		0.010	1.300	0.027	0.010	0.060
75/06/24	09 00		0.005	0.850	0.030	0.010	0.060
75/07/25	08 10		0.025	1.000	0.030	0.015	0.060

STORET RETRIEVAL DATE 76/05/04

462BC1
43 46 00.0 103 39 30.0 4
RUBY CREEK
46033 7.5 HERNE
T/STOCKADE LAKE
SEC RD BRDG 1.7 MI NW OF JCT W US HWY 16
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/04/12	14 10		0.095	1.150	0.042	0.035	0.050
75/05/05	13 50		0.005	0.900	0.010	0.015	0.020
75/05/22	13 45		0.010	2.200	0.055	0.020	0.080
75/06/11	09 10		0.015	1.150	0.035	0.020	0.040
75/06/24	09 40		0.020	3.300	0.055	0.035	0.050
75/07/25	08 35		0.010	1.100	0.025	0.040	0.080

STORET RETRIEVAL DATE 76/05/04

4628AA TF4627AA P001500
43 46 25.0 103 34 10.0 4
CUSTER
46033 7.5 CUSTER
T/STOCKADE LAKE
FRENCH CREEK
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
75/01/14	22 00		0.080	1.000	0.170	0.095	0.100K	0.200	0.200
75/02/13	10 30		0.240	1.000K	0.120	0.050	0.100K		0.200
75/03/17	13 30		0.080	1.000K	0.100	0.080K	0.100K	0.276	0.260
75/04/15	10 45		0.050	0.500K	0.075	0.093	0.240	0.205	0.287
75/05/18	14 15		0.050	0.690	0.050K	0.200	0.260		0.290
75/06/14	15 00		0.250	0.800	0.050K	0.460	0.530	0.253	0.292
75/07/14	08 30		0.050	0.640	0.025K	0.690	0.750	0.300	0.300
75/08/14	10 00		0.025	2.300	0.025K	1.300	1.500	0.220	0.300
75/09/15	14 45		0.025	1.500	0.088	1.100	1.300	0.210	0.200
75/10/16	13 00		0.025	2.300	0.025K	0.873	1.100	0.150	0.180
75/11/14	11 15		0.060	1.300	0.041	0.780	0.970	0.160	0.180
75/12/15	11 00		0.050	3.500	0.025K	0.540	0.650	0.130	0.140

K VALUE KNOWN TO BE
LESS THAN INDICATED

34

STORET RETRIEVAL DATE 76/05/04

4628AB P04627AB P003333
43 50 30.0 103 34 00.0 4
SYLVAN LAKE
46033 7.5 HILL CITY
T/STOCKADE LAKE
FRENCH CREEK
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
75/05/28	12	30	0.050	3.100	0.050	1.850	2.000	0.029	0.029
75/06/24	14	15	0.025	8.900	0.718	2.000	2.900	0.029	0.029
75/07/14	09	30	0.025	0.690	0.050	0.255	0.370	0.086	
75/07/29	10	00	0.025	2.600	0.100	0.259	0.440		
75/08/19	11	30	0.050	2.600	0.110	0.230	0.230	0.022	
75/09/02	09	30	0.075	2.900	0.225	0.150	0.220	0.001	
75/09/15	09	00	0.025	3.200	0.042	0.092	0.210	0.001	